Integrated Product Development Team (IPDT)

Status Reports

Communications

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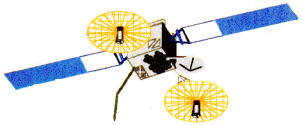
New Millennium Program Workshop

Communications Systems IPDT Status Report

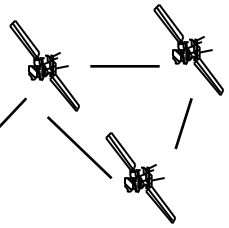
Dr. William Rafferty
JPL Co-Lead

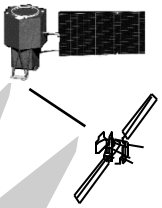
San Antonio, Texas
14–16 May, 1996

NASA Space Communications Needs



Interplatform Links and Networks

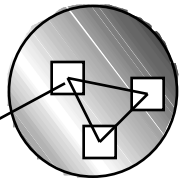


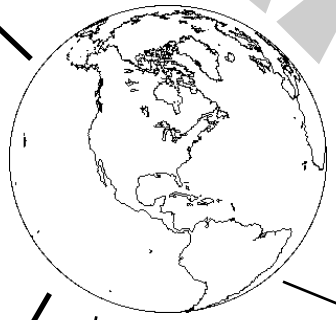


Intersatellite Links

Short Range, Low Power Communications Systems

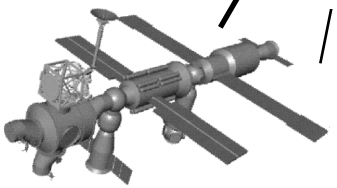
Fixed and Mobile Surface Networks



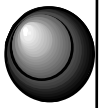


Orbiter-Surface Links

Extremely High Bandwidth Communications Systems



Direct-to-PI Links



Miniature Deep Space Communications Systems

Major Focus Areas

New Technologies/Techniques

- Lightweight, Low-power, Low-cost Components

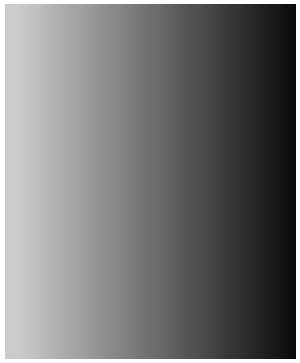
Multi-Mission Applications

New Communications Architectures/ Services

- Very High Bit Rate Links
- Short Range, Low Bit Rate Networks

Higher Frequency Bands

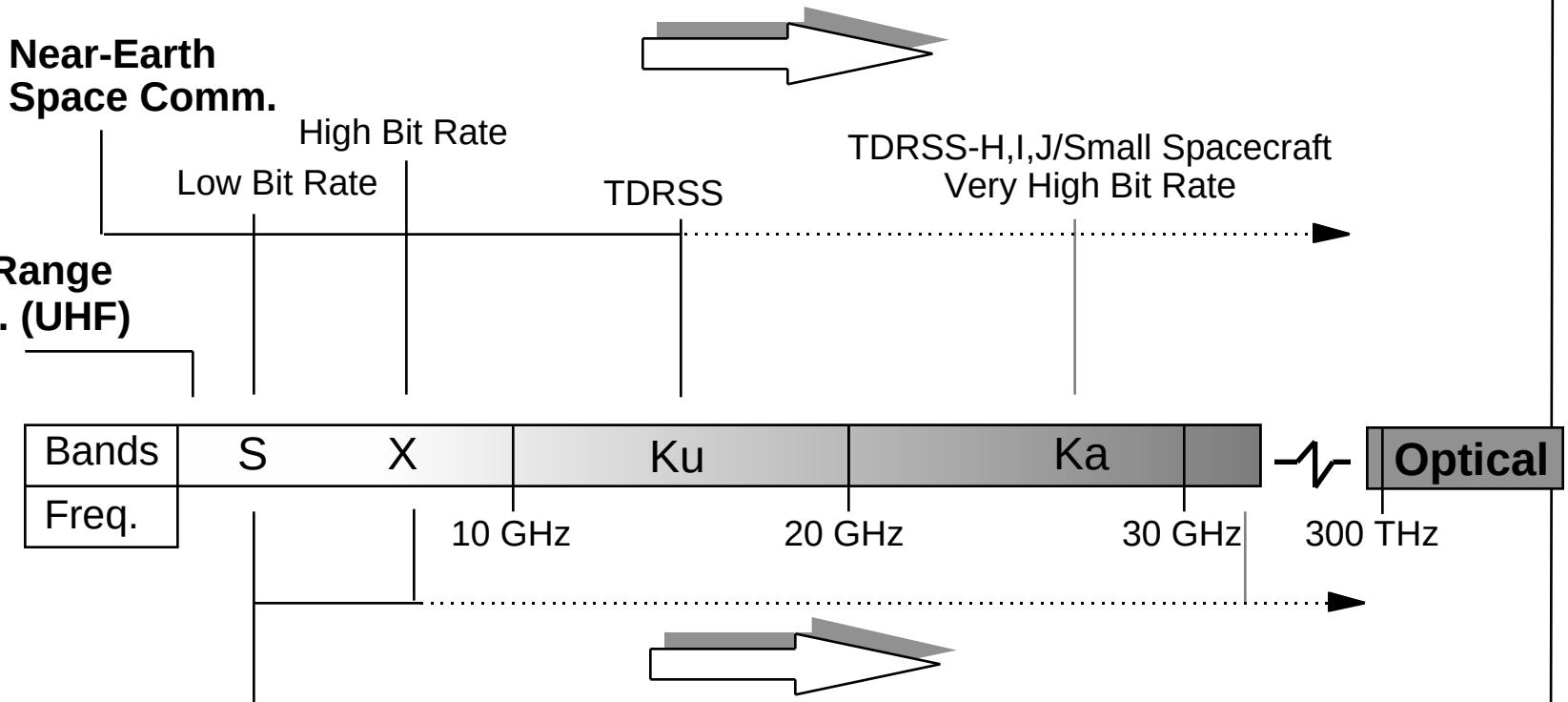
- Ka-band
- Optical



Small Spacecraft Telecom Systems

Spectrum Issues

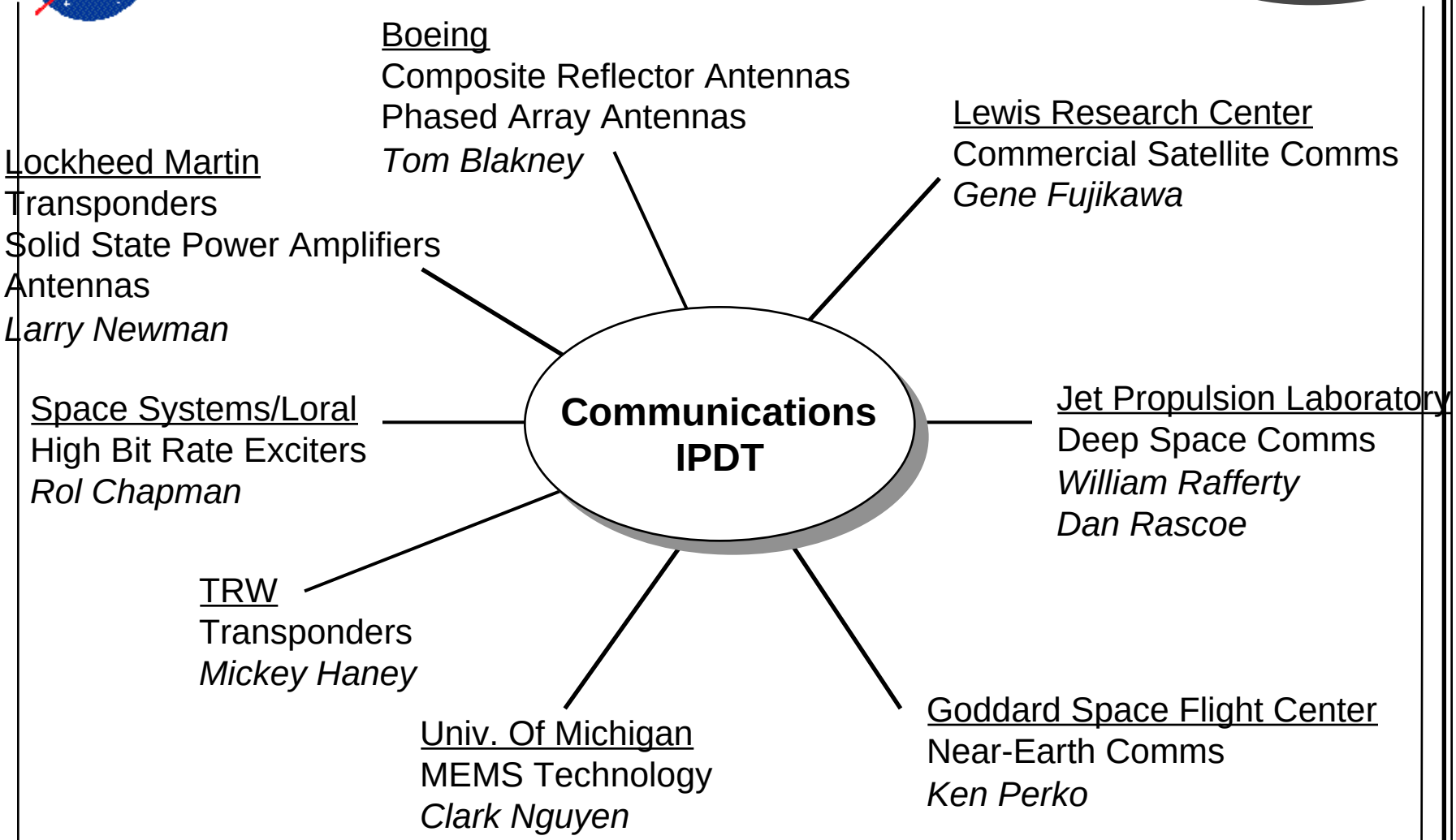
- Need for more bandwidth
- Regulatory pressures



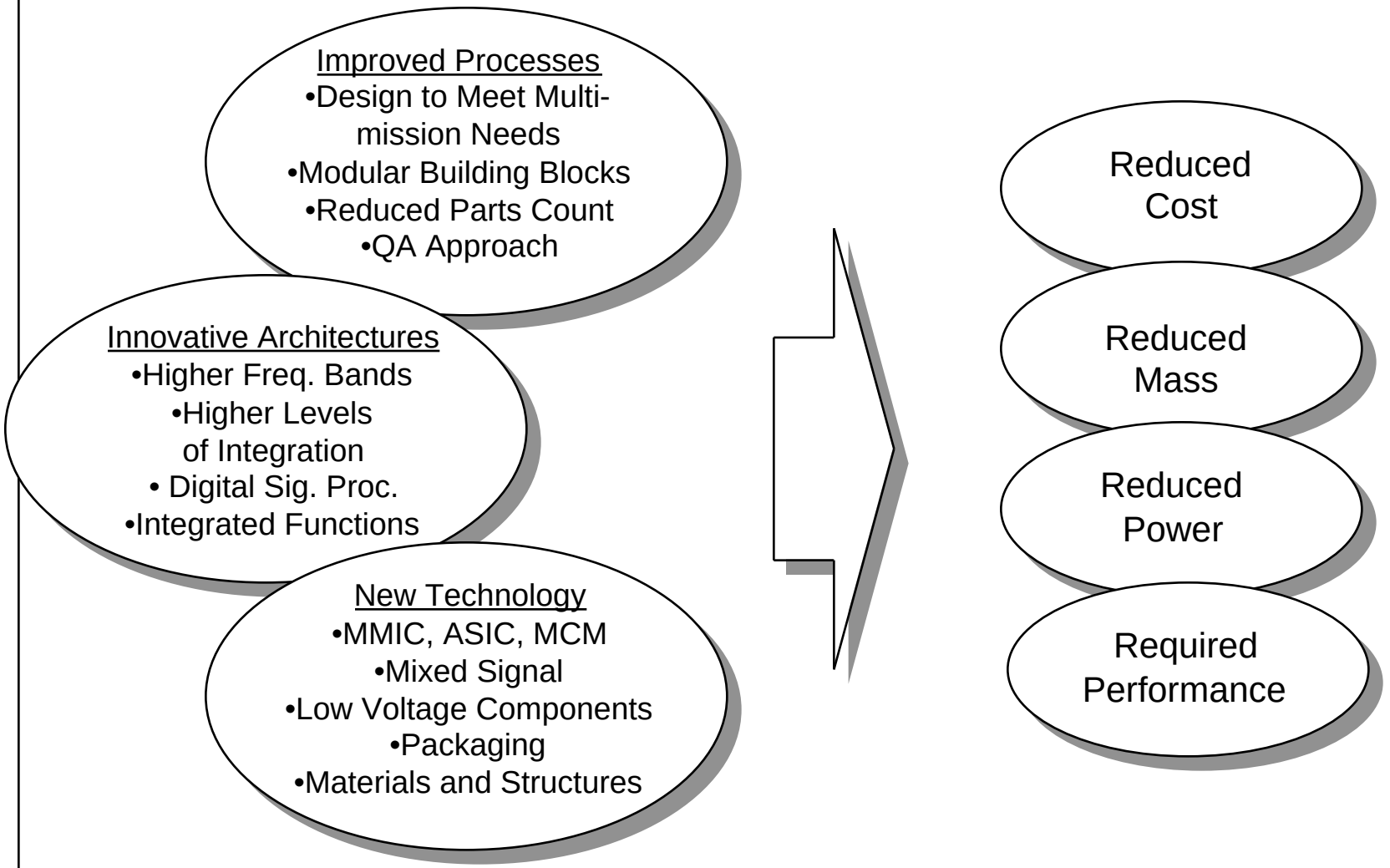
- Wavelength advantage
- Regulatory pressures
- Adjacent channel Interference

NASA space communications moving to higher frequencies

Team and Technology Areas



Approaches and Goals



Technology Roadmap Summary

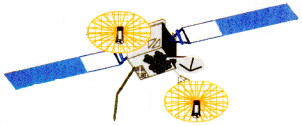
	FY 97	98	99	00
RF Deep Space Communications • Antennas (X-/Ka-band)		Composite Parabolic Inflatable X-band Only*	Deployable Reflectarray	Inflatable Ka-band*
• Power Amplifiers - SSPAs - MPMs		3-W, Hi-efficiency Ka-band 10-20 W, Hi-efficiency X-band	5-W, Hi-efficiency Ka-band 10 W, Hi-efficiency Ka-band	
• Miniature Transponder/Transceiver (X-/Ka-band)	Turbo Coding	Tiny Exciter	Tiny Transponder/ Transceiver	
RF Near-Earth Space Communications • High Bit rate, Phased Array Xmtrs		155 Mbps, X-band	622 Mbps, Ka-band and 8-PSK, ASIC Modulator	
• 4TH Generation NASA Transponder	TDRSS/ GSTDN	Ku-band Phased Array Transmitter Add-on		
Optical Communications • Deep Space		10-cm Aperture, 1-W Spacecraft Laser Terminal	Combined Flight Laser Comms and Imager Terminal	
• Near-Earth		1-cm Aperture, 0.1-W 0.5 Gbps LEO Laser Terminal	10-cm Aperture, 1-W 1+ Gbps GEO Laser Terminal	
Short Range, Low Bit Rate Communications • Single Chip Transceiver		* UHF Transceiver for Microprobe	MEMS Filters Demo's	MEMS Transceiver

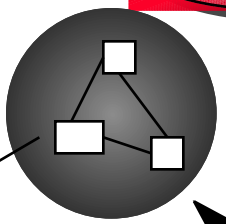
* DS-2 Telecom, to be developed by Comm IPDT

Candidate Technologies- Highlights

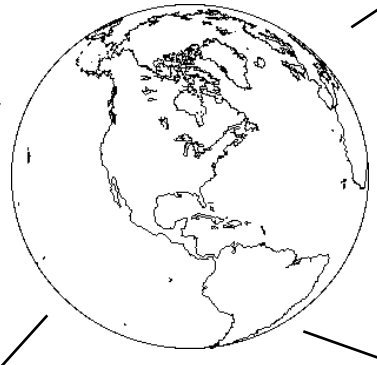
N M P

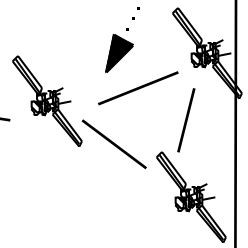
- Miniaturized, low-cost, X-/ Ka-band deep space telecom system

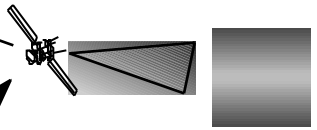




- RF Transceiver-on-a-chip







- Low-cost, small, X- & Ka-band phased array antennas
- Very high bit rate, integrated modulators and exciters (10 - 622 Mbps)

Optical Comm

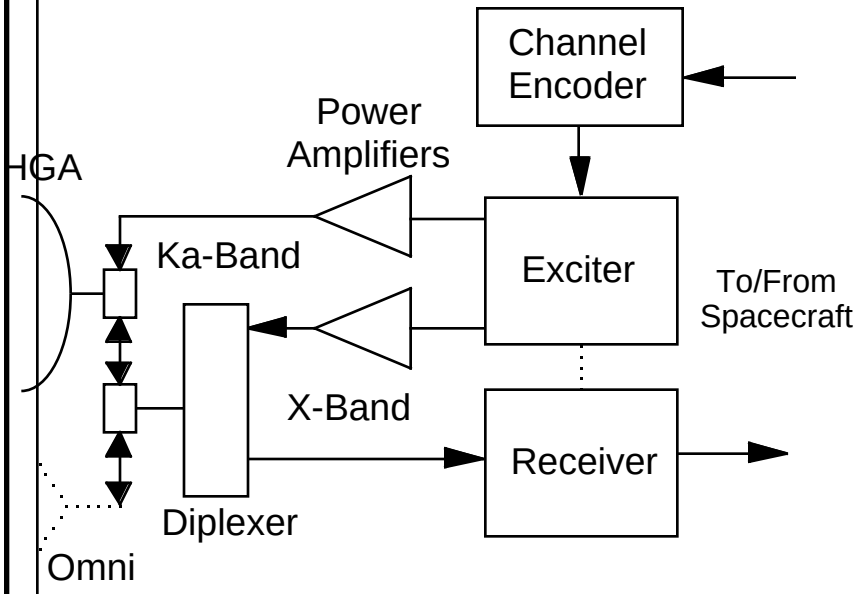
- High bit rate (0.5 - 1+Gbps) cross links & space-to-earth links for near-Earth applications
- Comm/science imager for deep space applications

Deep Space Communications Technologies

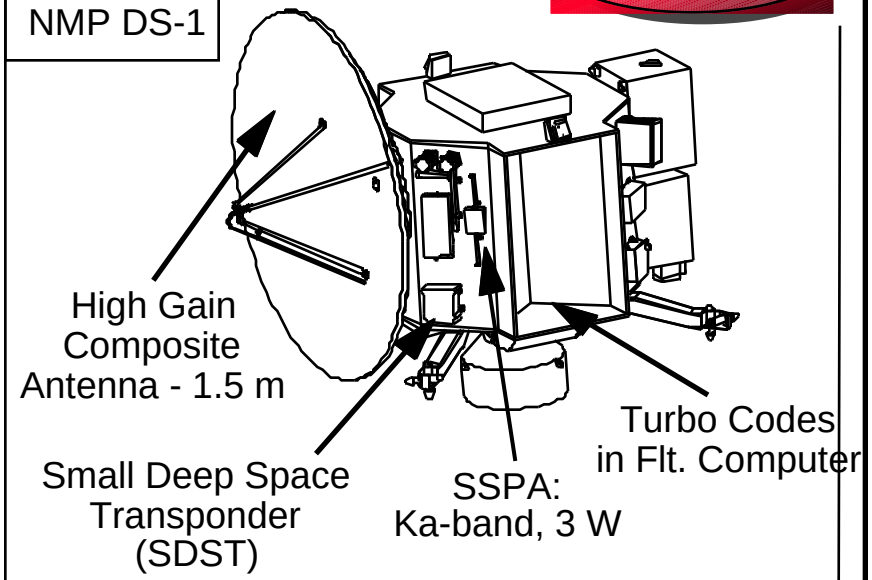
N M P

Spacecraft Telecom

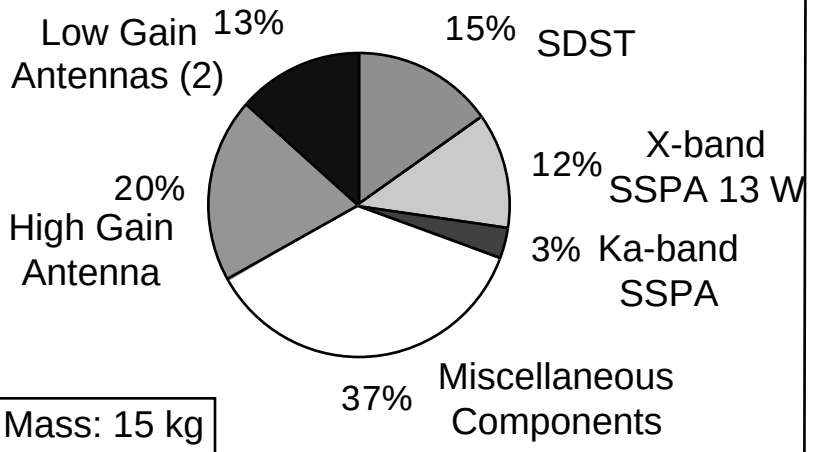
- Frequency Bands
  - X-/Ka-band
- Components
  - Antennas
  - High Power Amplifiers
  - Transponders/Transceivers
  - Passive Components
  - Channel and Source Coding



NMP DS-1

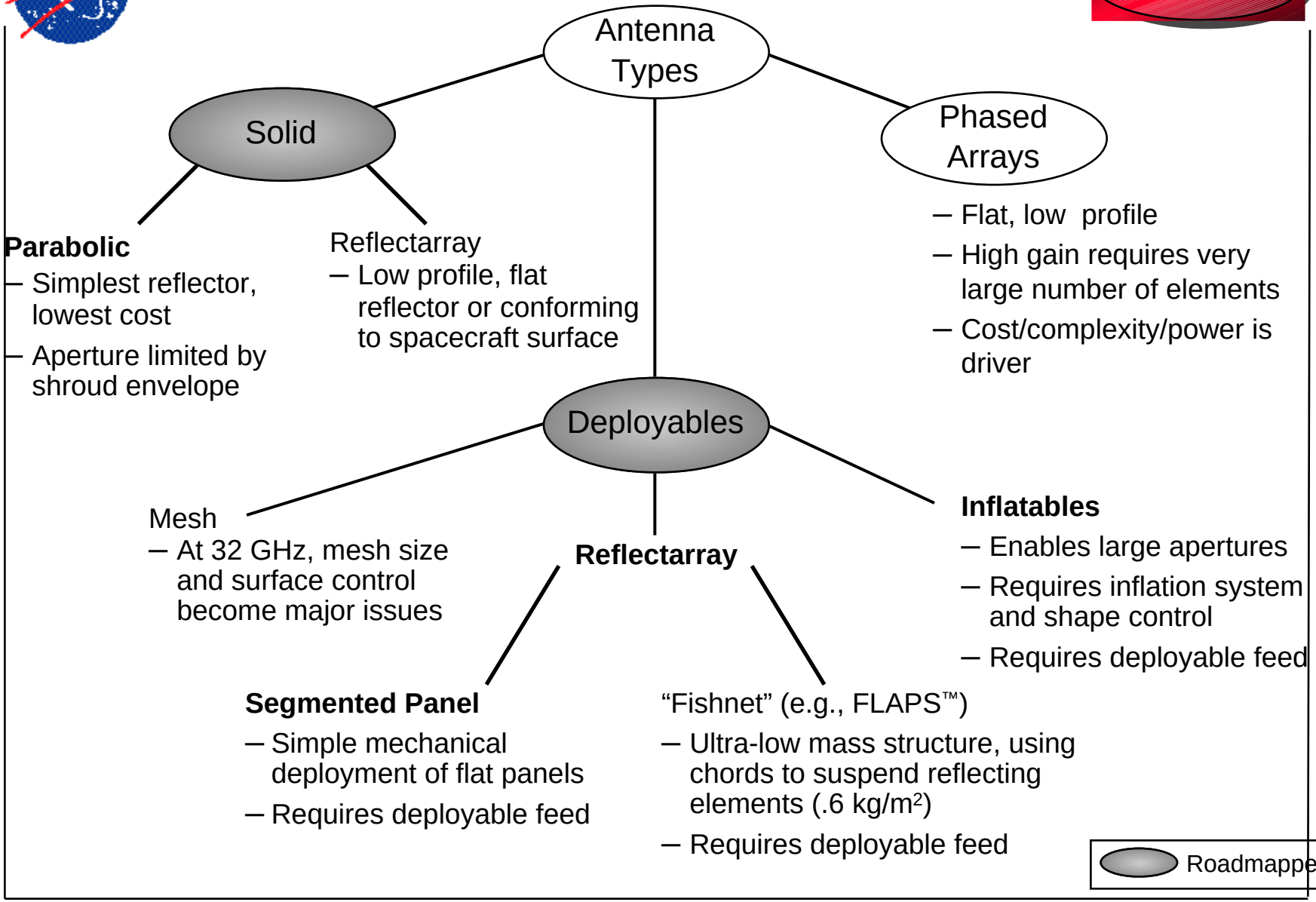


DS-1 Telecom Mass Budget



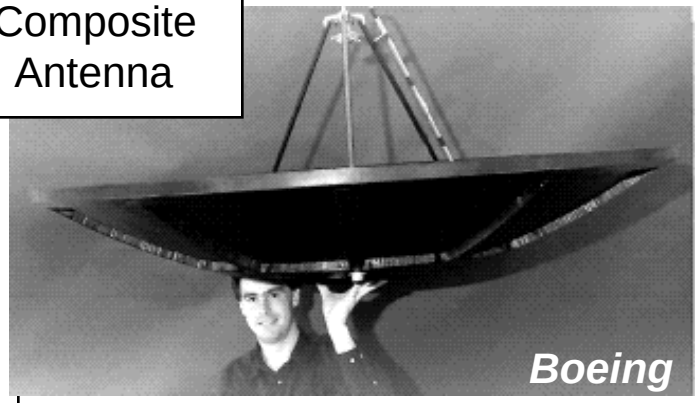
Mass: 15 kg

Proposed Deep Space Antenna Types



X-/Ka-Band Antennas

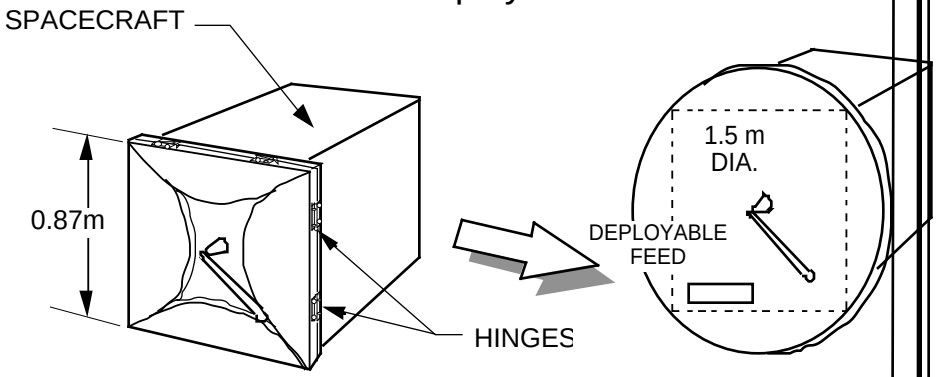
Composite Antenna



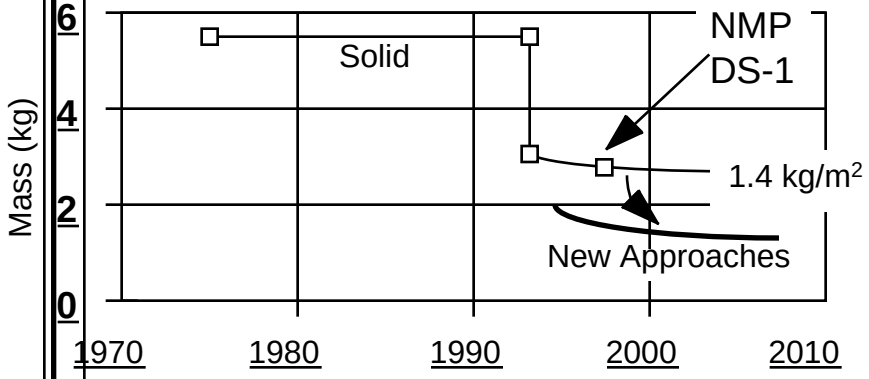
- Breadboard built for Pluto ATI Program
  - » Graphite composites, 1.5 m dia.
  - » Mass: 3.0 kg
- SV/DV = 1 (Stowed Vol./Deployed Vol.)

Deployable - Reflectarray

- Moderate SV/DV ~ 0.5
- Low Mass, 3.3 kg
- Low profile, surface mountable
- Deployable feed



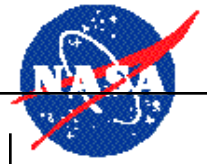
Reflector Trends (1.5 m)



Inflatable Parabolic

- SV/DV ~ 0.1
- Surface Accuracy: <1mm rms
- Mass: 2.7 kg

Power Amplifiers



Power Amplifiers

- Compact
- Miniature EPCs
- High Efficiency

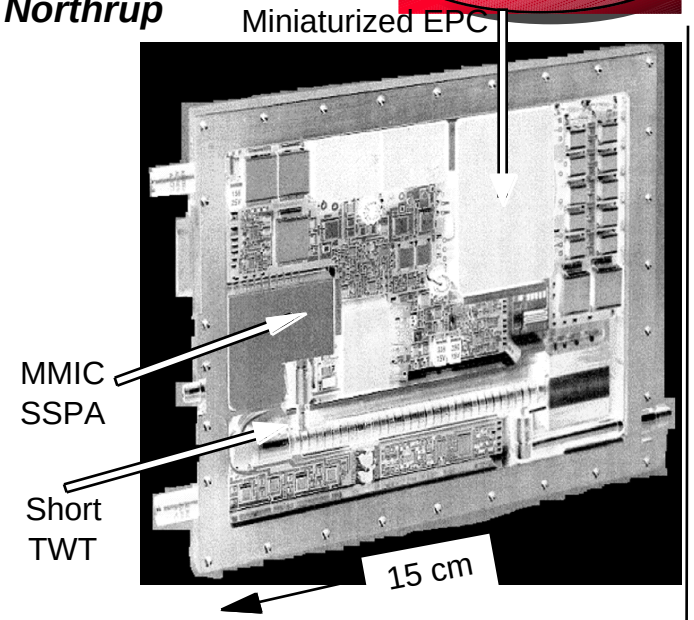
Solid State Power Amplifier (SSPA)

- State-of-Art PHEMT Devices/MMICs
- "Credit Card" size EPC
- Mass: 0.25 - 0.5 kg
- High Density Packaging

Microwave Power Module (MPM)

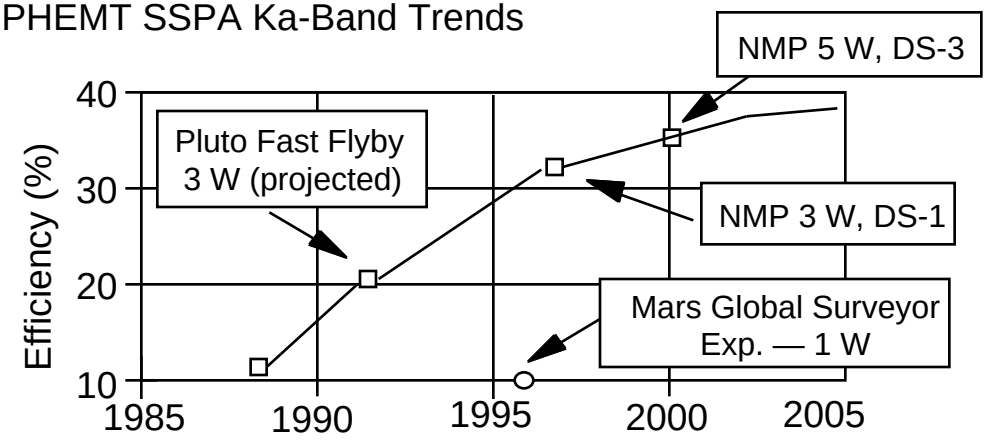
- MMIC SSPA Driver and Short TWT
- 50% and 39 % PAE predicted for X-/Ka-band
- Comparison to Cassini TWT
  - 40% lighter (1.4 kg)
  - 90% smaller (327 cc)

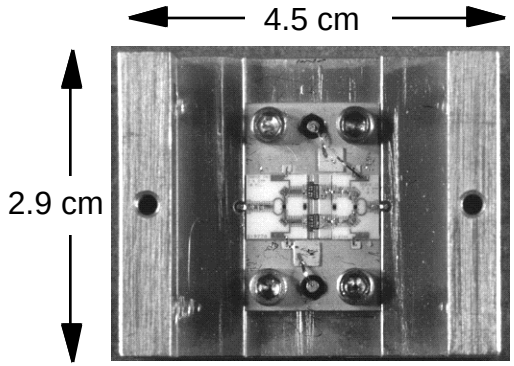
Northrup



Microwave Power Module (MPM)

PHEMT SSPA Ka-Band Trends

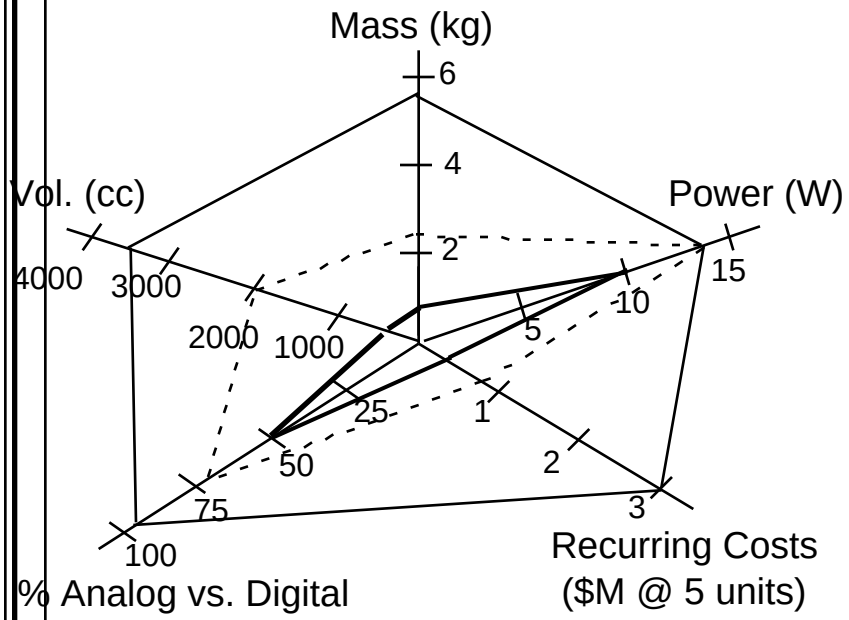




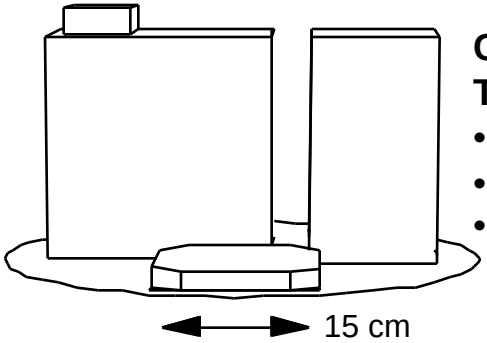
SSPA Lockheed Martin (1.5 W, PFF)

Transponder Developments

Key Metrics

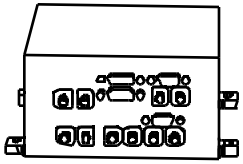


Legend	
———	Cassini
- - - -	SDST (predicted)
———	DSTT (predicted)



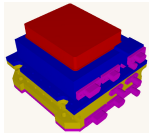
Cassini DST, CDU & TMU ('96 first use)

- Mostly analog design
- 1 MMIC; 4,000 parts
- Hybrid technology



Small Deep Space Transponder SDST ('98)

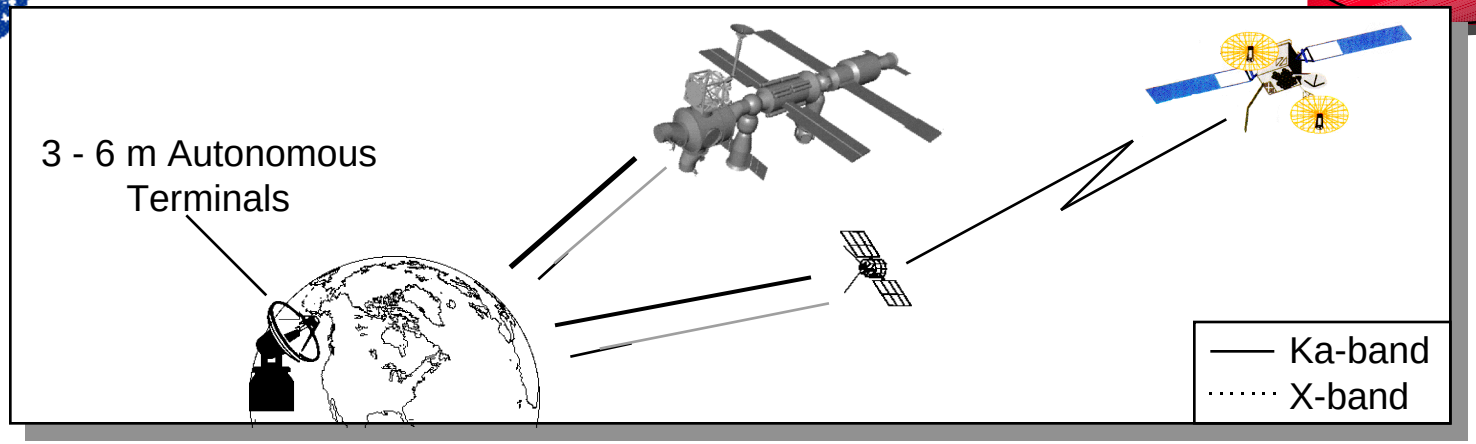
- Digital implementation of analog design
- Integrated TMU & CDU
- 1 ASIC; 1,100 parts

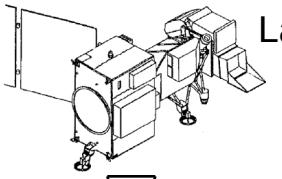


Deep Space Tiny Transponder (DSTT) ('00)

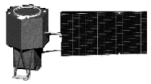
- Full application of digital processing techniques
- 4 ASICs, 3 RF MCMs
- <500 parts

Near-Earth Communications Technologies





Landsat 7



NMP EO-1

NMP EO-2

Launch 2Q98

Launch 4Q98

Benchmark

- Gimbaled Antenna
- Discrete Power Amp.
- 150 Mbps/ 6-m ground antenna

High Rate Transmitter

- √ Landsat 7 and EOS compatible
- √ Phased Array-based
- 10- 155 Mbps
- 8-PSK for higher bandwidth efficiency
- √ Advanced Compression
- 4th Generation S-band Transponder

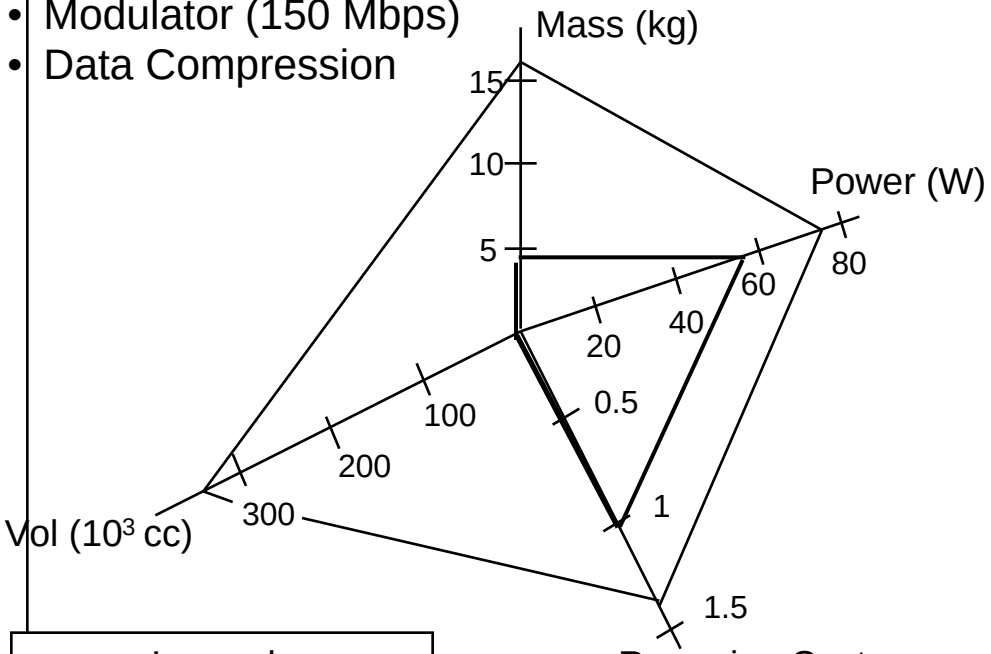
Very High Rate Transmitter

- New capability, TDRS H,I,J compatible
- Phased Array-based
- Space-to-ground at very high data rate (622+ Mbps)
- Low Earth orbit to TDRSS: ≤10 Mbps
- ASIC-based vector modulator
- Goal: Exceed Benchmark, except for Raw DC

High Data Rate Subsystem

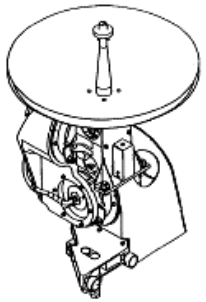
Key Metrics for NMP X-band Transmitter Subsystem:

- Phased Array Antenna
- Power Amplifier
- Modulator (150 Mbps)
- Data Compression



Benchmark

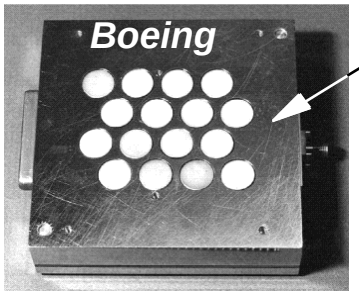
Landsat 7



66 cm

Gimbaled X-Band High Gain Dish Antenna

New Millennium Concept



Sub-Array 10x10x3 cm

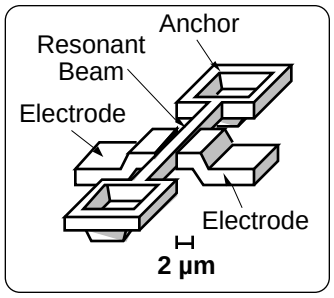
Full Array 25x25x3 cm

X-Band Phased Array, including RF Amplifiers

Short Range Telecom

Characteristics

- Inter-spacecraft, surface, and orbiter communication links, UHF – S-band
- Single chip transceiver for broadcast/point-to-point applications
- Chip set (2) for high rate, symmetrical network node
- Low cost, low power, ASIC-based designs, exploiting commercial developments
- Selectable bit rate and modulation type
- Bit Rate x Distance^2 product ~ 10^{10}
  - » < 500 kbps, 0.1 - 2000 km
- Micro-Electro-Mechanical Systems (MEMS) technology
  - » Micron-level analog components
  - » Sensor implementation on Telecom Chip

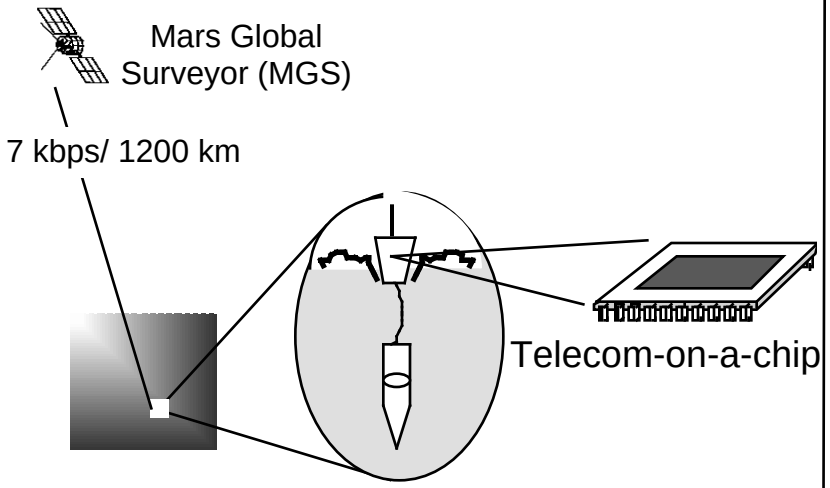


Univ. Of Michigan

MEMS Resonator High-Q Block
- Oscillator/VCO
- Filter/Diplexer

NMP DS-2: Mars Microprobe

- Programmable transceiver module
- Survive landing ~ 100, 000 g
- 0.1 - 100's kbps
- UHF transmit/receive (~ 400MHz)
- Half-duplex mode
- 10 - 640 mW transmit power, on-chip
- Mass < 20 gm, vol. < 8 cm^3
- Low power receiver < 1 mW
- Mixed signal, silicon (BiCMOS) ASIC with low unit costs



Optical Communications Terminal Developments

Characteristics

- 10-100 X more data rate than RF
- Up to 1/2 the mass of RF
- 1/10 to 1/20 the size of RF antenna
- Cost comparable to existing RF

- No increased platform stability needed
- Can be steered relative the S/C axis
- Accommodates ranging for S/C navigation

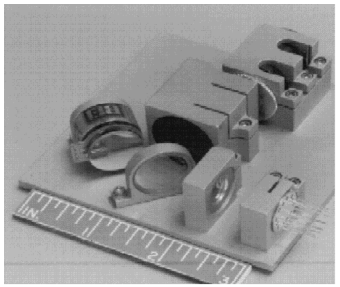
- Comm terminal can also be used for collecting science images
- Optical signals not regulated by FCC

- Network of receivers required to be deployed for spatial diversity to overcome propagation impairments — clouds rains

- NASA-JPL terminal developments focused on Reduced complexity architectures:
  - Single steering mirror
  - Single Acq/Trk detector
  - Controllable point-ahead
  - Lightweight optics & gimbals

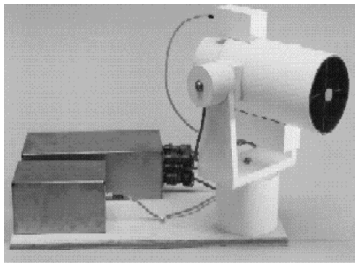
Terminals Under Development At NASA-JPL

LEO Terminal



- 0.5 Gbps from LEO
- 5 kg, 15 W, <4000 cc, incl. gimbal
- 1-cm aperture, 0.3 W semiconductor laser
- 1.0-m receive aperture

GEO/Deep Space Terminal



- 1+ Gbps @ Geo, 500 kbps @ 1 AU
- Dual use with imager
- 8 kg, 22 W, ~4700 cc , incl. gimbal
- 10-cm aperture, 1-W solid state laser
- 3.5-m receive aperture

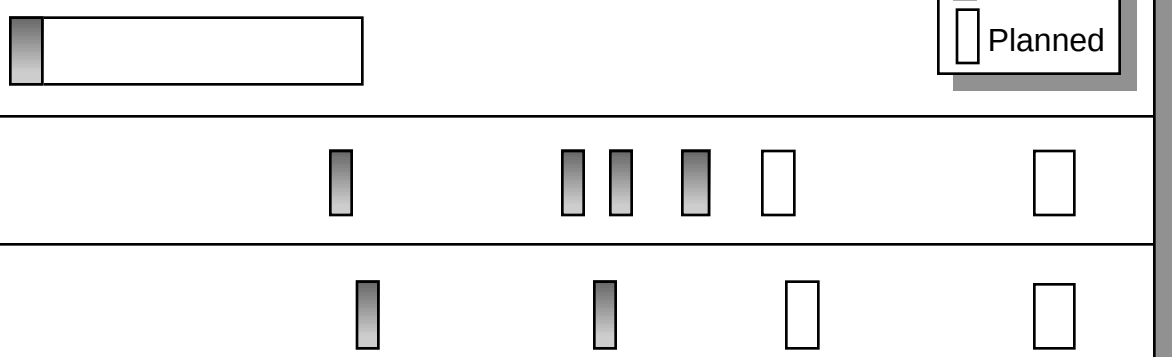
Summary

- The Communications Systems IPDT has worked well as a team
  - » The Team has benefited greatly from interactions and open discussion of technology targets
  - » Individual Industry/Academia Members have brought significant capabilities through their own expertise and those of their respective organizations
- The Roadmap contains technologies/approaches that meet the thrusts established for the IPDT
- The Team expects the Roadmap to be updated as:
  - » New technologies emerge
  - » New Members come on board
  - » Gaps are identified and filled

NASA Spectrum Overview

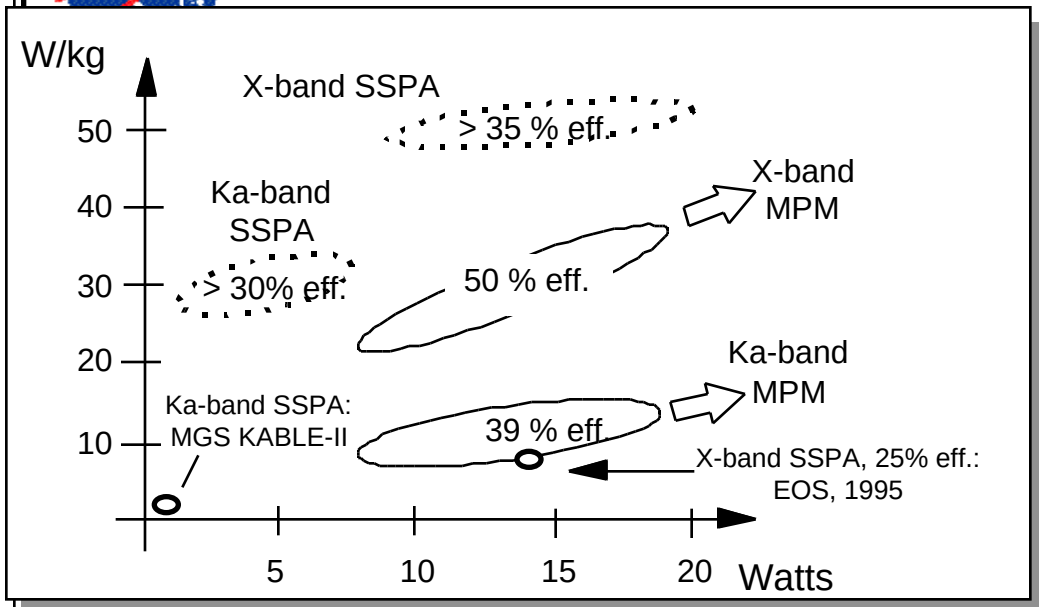
Wavelength, cm	100	10	1	10^{-4}
Frequency Band	UHF	S	X Ku Ka	Optical

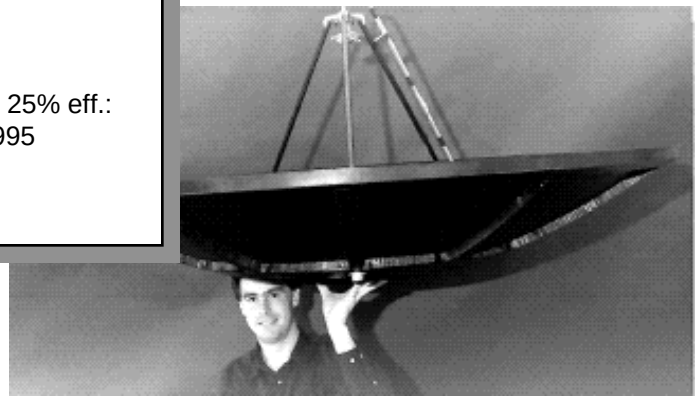
COMM AREAS	
Short Range	
Near-Earth	
Deep Space	

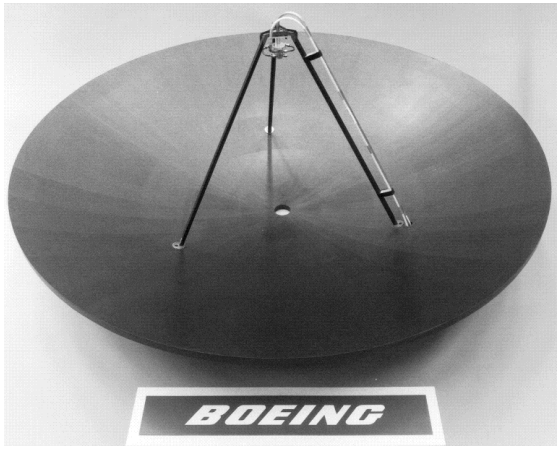


Moving To Higher Frequency Bands

- Need for more bandwidth
- Wavelength advantage
- Exploit adjacent band synergy
- Regulatory pressures
- Adjacent channel Interference


W/kg
50
40
30
20
10
X-band SSPA
> 35 % eff.
Ka-band
SSPA
> 30% eff.
X-band
MPM
50 % eff.
Ka-band
MPM
39 % eff.
Ka-band SSPA:
MGS KABLE-II
X-band SSPA, 25% eff.:
EOS, 1995
5
10
15
20
Watts




BOEING